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Duane Arnold Energy Center

CEDAR RIVER OPERATIONAL ECOLOGICAL STUDY ANNUAL REPORT

January 1994 - December 1994

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March 1995

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INTRODUCTION

This report presents the results of the physical, chemical, and biological studies of the Cedar River in the vicinity of the Duane Arnold Energy Center during the 21st year of station operation (January 1994 to December 1994).

The Duane Arnold Energy Center Operational Study was implemented in mid-January, 1974. Prior to plant start-up extensive preoperational data were collected from April, 1971 to January, 1974. These preoperational studies provided a substantial amount of "baseline" data with which to compare the information collected since the station became operational. The availability of the 21 years of operational data, collected under a variety of climatic and hydrological conditions, provides an excellent basis for the assessment of the effects of the operation of the Duane Arnold Energy Center on the limnology and water quality of the Cedar River. Equally important is the availability of sufficient data to identify long-term trends in the water quality of the Cedar River which are unrelated to station operation, but are indicative of climatic patterns, changes in land use practices, or pollution control procedures within the Cedar River basin.

SITE DESCRIPTION

The Duane Arnold Energy Center, a nuclear fueled electrical generating plant, operated by the Iowa Electric Light and Power Company, is located on the west side of the Cedar River, approximately two and one-half miles north-northeast of Palo, Iowa, in Linn County. The plant employs a boiling water nuclear power reactor which produces approximately 560 MWe of power (1650 MWth) at full capacity. Waste heat rejected from the turbine cycle to the condenser circulating water is removed by two closed loop induced draft cooling towers which require a maximum of 11,000 gpm (ca. 24.5 cfs) of water from the Cedar River. A maximum of 7,000 gpm (ca. 15.5 cfs) may be lost through evaporation, while 4,000 gpm (ca. 9 cfs) may be returned to the river as blowdown water from the cool side of the cooling towers.

OBJECTIVES

Studies to determine the baseline physical, chemical, and biological characteristics of the Cedar River near the Duane Arnold Energy Center prior to plant start-up were instituted in April of 1971. These preoperational studies are described in earlier reports.[1-3] Data from these studies served as a basis for the development of the operational study.

The operational studies were designed to identify and evaluate any significant effects of chemical or thermal discharges from the generating station into the Cedar River, as well as to assess the magnitude of impingement of the fishery on intake screens or entrainment in the condenser make-up water. These were first implemented in January, 1974 and have continued without interruption through the current year.[4-23]

The specific objectives of the operational study are twofold:

1. To continue routine water quality determinations in the Cedar River in order to identify any conditions which could result in environmental or water quality problems.
2. To conduct physical chemical, and biological studies in and downstream of the discharge canal and to compare the results with similar studies executed above the intake. This will make possible the determination of any water quality changes occurring as a result of chemical additions or condenser passage, and to identify any impacts of the plant effluent on aquatic communities downstream of the discharge.

STUDY PLAN

During the operational phase of the study sampling sites were established in the discharge canal and at four locations in the Cedar River (Figure 1): 1) upstream of the plant at the Lewis Access Bridge (Station 1); 2) directly upstream of the plant intake (Station 2); 3) at a point within the mixing zone approximately 140 feet downstream of the plant discharge (Station 3); and 4) adjacent to Comp Farm, located about one-half mile below the plant (Station 4). Samples were also taken from the discharge canal (Station 5).

Prior to 1979, samples were collected and analyzed by the Department of Environmental Engineering of the University of Iowa. From January, 1979 through December, 1983 samples were collected and analyzed by Ecological Analysts, Inc. Since 1984 collection and analysis of samples has been conducted by the University of Iowa Hygienic Laboratory, located in Iowa City, Iowa. The conclusions contained in this annual report are based on the results of their analyses. Samples for routine physical, chemical, and biological analysis were taken twice per month, while other studies were conducted seasonally. The following are discussed in this report:

I. General Water Quality Analysis

A. Frequency: twice per month

B. Location: at all five stations

C. Parameters Measured:

1. Temperature
2. Turbidity
3. Solids (total, dissolved, and suspended)
4. Dissolved oxygen
5. Carbon dioxide
6. Alkalinity (total and carbonate)
7. pH
8. Hardness series (total and calcium)
9. Phosphate series (total and ortho)
10. Ammonia
11. Nitrate
12. Iron
13. Biochemical oxygen demand
14. Coliform series (fecal and *E. coli*)

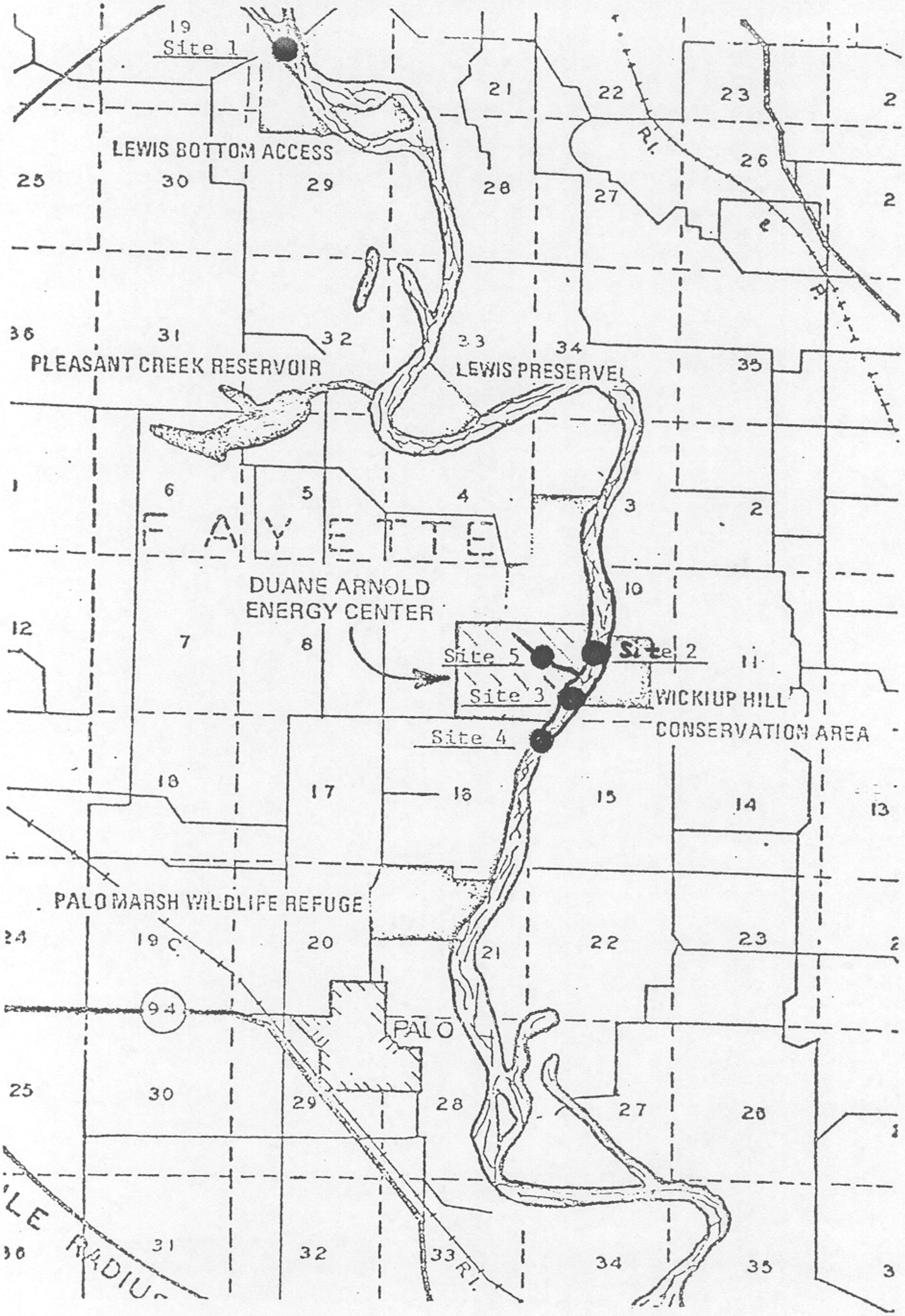

Figure 1. Location of Operational Sampling Sites

II. Additional Chemical Determinations

A. Frequency: twice yearly

B. Locations: at all five stations

C. Parameters Measured:

1. Chromium
2. Copper
3. Lead
4. Manganese
5. Mercury
6. Zinc
7. Chloride
8. Sulfate

III. Biological Studies

A. Benthic Studies:

1. Frequency: summer and fall
2. Location: at all five stations

B. Impingement Studies:

1. Frequency: daily
2. Location: intake structure

C. Asiatic Clam (Corbicula) and Zebra Mussel (Dreissena) Surveys:

1. Frequency: twice yearly
2. Location: upstream and downstream of the plant, intake bay, cooling tower basin, and discharge canal. The Zebra mussel survey also included Pleasant Creek Reservoir.

OBSERVATIONS

Physical Conditions

Hydrology (Table 1)

River flows during 1994 were far lower than those present in 1993. Estimated mean flow for 1994 was 4701 cfs, less than a third of that present in 1993 and slightly less than the average flow of 5312 cfs observed during the 23 years of the Cedar River water quality study. Mean monthly discharge at the U.S. Geological Survey gauging station in Cedar Rapids ranged from 956 cfs in January to 7939 cfs in March. Flows were in excess of the 1961-1990 monthly median discharges in all months except January, April and May. Lowest daily river flows occurred in January. An estimated low flow of 730 cfs was reported on January 9 while a maximum daily river discharge of 20,400 cfs occurred on March 9. River flows were below 1500 cfs from January through mid February and then increased to the yearly maximum of 20,400 cfs in March. Flows declined by mid March and remained below 5000 cfs from late March until mid June when they again increased reaching a summer peak of 13,300 cfs on June 28. Flows in July ranged from ca 5300 to 11,400 cfs. Discharge was lower in August and September. With the exception of a peak of ca 9500 cfs in mid August most river flows remained below 5000 cfs until late September when they increased to ca 6900 cfs. October flows ranged from ca 4700 to 7000 cfs. November and December flows were lower ranging from ca 2700 to 4800 cfs. hydrological data are summarized in Table 1.

Temperature (Table 2)

Ambient upstream river temperatures during 1994 ranged from 0.0°C (32.0°F) to 26.5°C (79.7°F). The maximum ambient (Station 2) temperature was observed on June 22. This value was 4.0°C (7.2°F) above that observed in 1993 and similar to the 1980 to 1992 average maximum of 26.8°C (80.2°F). Maximum downstream temperatures of 26.5°C (79.7°F) were also observed at Station 3 and 4 on June 22. The highest discharge canal (Station 5) temperature observed during the period was 30.5°C (86.9°F), which was recorded on July 5. A maximum temperature differential (ΔT value) between the upstream river and the discharge canal (Station 2 vs. Station 5) of 18.5°C (33.3°F) was observed on December 1.

Station operation continued to have a negligible effect on downstream water temperatures. The maximum ΔT value between ambient upstream temperatures at Station 2 and downstream temperatures at Station 3, located in the mixing zone for the discharge canal, of 1.0°C (1.8°F) was measured in February. Maximum temperature elevations at the Comp Farm station, one-half mile below the plant (Station 2 vs. Station 4) were also 1.0°C (1.8°F) in April and May. Obviously there was no instance in which a temperature elevation in excess of the Iowa water quality standard of 3°C was observed. A summary of water temperature differentials between upstream and downstream locations is given in Table 3.

Turbidity (Table 4)

Average river turbidity values were the lowest observed since 1990. A peak value of 100 NTU occurred at both upstream and downstream river locations in June. Low values (2-4 NTU) occurred in January and February. Turbidity values in the discharge canal were consistently higher than those observed in the upstream river. A maximum discharge canal turbidity of 360 NTU was observed on June 22.

Solids (Tables 5-7)

Solids determinations included total, dissolved, and suspended. Total solids values in upstream river samples were slightly lower than those observed in 1993.[23] Values ranged from 230 to 520 mg/L, with the majority falling between 350 and 400 mg/L.

Dissolved solids values were similar to those present in 1993. Upstream values ranged from 170 to 380 mg/L. Values of less than 250 mg/L occurred at intervals in April, May, June, August and September. High values continued to occur in the winter. As in most previous years, dissolved solids values at Station 3 and 4, downstream of the discharge canal, were only slightly higher than values observed upstream. Maximum downstream values of 410 mg/L were observed at Station 3 on February 17.

Suspended solids values at river locations were lower than those of the previous year ranging from 2 to 180 mg/L. Low values occurred in January, February and December while highest values occurred during late June.

As in previous years, total and dissolved solids values in the discharge canal were much higher than in the river samples. Maximum total solids concentrations of 2600 mg/L were observed in the discharge canal in May while a minimum values of 400 and 440 mg/L were observed in February and December. All other total solids values in the discharge canal were in excess of 1000 mg/L. Dissolved solids levels in the discharge canal ranged from 360 mg/L in early February to 2300 mg/L in mid May. Suspended solids values in the discharge canal were also consistently higher than those present at river locations but differences were not as apparent as they were in the case of total or dissolved solids.

Chemical Conditions

Dissolved Oxygen (Table 8)

Dissolved oxygen concentrations in river samples collected during 1994 were somewhat higher than those of 1993[23], ranging from 7.0 to 15.3 mg/L (87 to 144% saturation). High dissolved oxygen concentrations (ca. 12-14 mg/L) continued to occur in the river in winter when temperatures were low and the solubility of the gas was highest, but supersaturated oxygen values were observed in the spring in conjunction with algal photosynthesis. Lowest values occurred in late June and late July.

Dissolved oxygen concentrations in the discharge canal (Station 5) ranged from 4.1 to 13.0 mg/L (53 to 89% saturation).

<u>Carbon Dioxide</u> (Table 9)

Carbon dioxide concentrations in river samples were usually somewhat lower than those present in 1993[23], ranging from <1 to 9 mg/L. From April through December values were generally below 1 mg/L. Maximum levels (7-9 mg/L) occurred in January, February and March. Values in the discharge canal could not be precisely determined but, based on pH levels, were probably higher.

<u>Alkalinity, pH, Hardness</u> (Tables 10-14)

These interrelated parameters were influenced by a variety of factors, including hydrological, climatic, and biological conditions. Total alkalinity values in the 1994 river samples were generally higher than those present in 1993.[23] River values ranged from 134 to 264 mg/L. Lowest values occurred in mid May and mid August. Unlike the drought years of 1988 and 1989, lowest values did not occur during periods of low flow. Highest values occurred during January.

Carbonate alkalinity was not present in river samples from January through March or at intervals from June through October. A maximum value of 18 mg/L was observed in June due likely to increased algal activity.

Values for pH in river samples were higher than those observed in 1993[23], ranging from 7.6 to 9.1. Highest values occurred in May and June. As in previous years, highest levels accompanied increased photosynthetic activity while low values occurred during the winter.

Total hardness values in the upstream river were somewhat lower than those present in 1994 and generally paralleled total alkalinity levels. The highest values (300-395 mg/L) occurred during the winter and late fall, while low values of ca 200 mg/L occurred during a period of relatively low river flow in May.

Hardness values in the discharge canal continued to be consistently higher than upstream river values; a result of reconcentration in the blowdown. Total hardness levels in the discharge canal ranged from 340 to

1500 mg/L. Levels downstream of the station however were not generally higher than upstream values.

Calcium hardness values paralleled total hardness values. Concentrations ranged from 85 to 250 mg/L in the river and from 230 to 905 mg/L in the discharge canal.

Phosphates (Table 15 and 16)

Total phosphate concentrations in river samples were similar to 1993[23] levels. Concentrations in the river ranged from <0.1 to 0.9 mg/L. High levels occurred in mid March. Low values, 0.1 mg/L or less, occurred in February, May, November and December. Levels in the discharge canal were consistently higher than those observed in the river. Discharge canal values ranged from 0.1 to 3.0 mg/L.

Orthophosphate concentrations in river samples were somewhat lower than those present in 1993 due likely to greater uptake by the larger algal populations present. Values ranged from <0.1 mg/L during much of the year to 0.4 mg/L in March.

Ammonia (Table 17)

Average ammonia concentrations in the river were the highest observed since 1989 (Table 17). Although concentrations were below detection limits (<0.1 mg/L as N) from April through early December, high concentrations, 0.5 to 0.9 mg/L (as N) occurred from mid January through March.

Nitrate (Table 18)

Average nitrate concentrations in the river were the lowest present since 1989 (Table 27). During the current year nitrate values in upstream river samples ranged from 1.6 to 7.5 mg/L (as N). Maximum levels (>6 mg/L as N) generally occurred in the late fall and winter and from mid June through July. Minimum levels occurred in September.

Nitrate concentrations were consistently higher in the discharge canal than in river samples. A maximum nitrate concentration of 28 mg/L (as N) was observed in the discharge canal on June 22. Downstream nitrate concentrations were similar to upstream levels.

Iron (Table 19)

Iron concentrations in the river were generally higher than those present during 1993.[23] Concentrations ranged from 0.07 to 4.7 mg/L. The maximum value was observed on July 21. Low values occurred in January and February. As in previous years, high iron concentrations were observed in association with increased turbidity and suspended solids, indicating that most of the iron present was in suspended form rather than in solution. Iron levels continued to be consistently higher in the discharge canal. A maximum iron value of 10 mg/L was observed in the canal on July 21.

Biological Studies

Biochemical Oxygen Demand (Table 20)

Five day biochemical oxygen demand (BOD_5) values were substantially higher than those present in 1993[23] ranging from <1 to 19 mg/L and, averaging 5.3 mg/L in 1994 as compared to 2.3 mg/L in 1993 (Table 27). Highest values occurred in May, June and September in conjuction with algal blooms. Lowest values, <1 mg/L, occurred during the winter.

Coliform Organisms (Tables 21 and 22)

Coliform determinations included enumeration of fecal coliforms as well as specific determination of *Escherichia coli*.

Maximum river levels of fecal coliform and *E. coli* of 9,500 and 6,700 organisms/100 ml, respectively, were observed at the downstream location (Station 3) in early July. Low values of 20 or less organisms/100 ml were observed in early April. Fecal coliform and *E. coli* levels in the discharge canal exhibited considerable variation from river values but were not consistently higher or lower than at river locations. Maximum fecal coliform and *E. coli* concentrations of 4,200 and 4,100 organisms/100 ml, respectively, were observed in samples from the discharge canal on June 22.

ADDITIONAL STUDIES

In addition to the routine monthly studies a number of seasonal limnological and water quality investigations were conducted during 1994. The studies discussed here include additional chemical determinations, benthic surveys, asiatic clam (Corbicula) and zebra mussel (Dreissena) surveys, and impingement determinations.

Additional Chemical Determinations

Samples for additional chemical determinations were collected on April 7 and July 21, 1994 from all river locations and from the discharge canal and analyzed for chlorides, sulfates, chromium, copper, lead, manganese, mercury, and zinc. With few exceptions, concentrations of all parameters fell within the expected ranges. Chloride and sulfate levels were somewhat higher at all river locations on both sampling dates than in 1993 due likely to lower river flows and less dilution by runoff during the current year. Levels of the heavy metals chromium and mercury were below detection limits in all samples. An elevated lead level of 26 ug/L was present in the mixing zone at Station 3, 140 feet downstream of the discharge canal on April 7. This is the first time that a lead concentration in excess of 10 ug/L had been observed in the study since August 1983. However this elevated level is still below the Iowa water quality standard and lead concentrations at all other locations were below the 10 ug/L detection limit. The cause of this relatively high lead level could not be determined but the absence of detectable lead concentrations in the discharge canal or at other locations indicate that it was probably unrelated to station operation and was not sufficiently high to adversely affect the water quality of the Cedar River. Lead concentrations were at or below the detection limit in all other river and discharge canal samples on both sampling dates. On July 21 a copper concentration of 60 ug/L, which is in excess of the chronic criteria for copper of 35 ug/L for class B waters[24], was observed upstream of the station at the Lewis Access location (Station 1) but copper concentrations in the other three river samples and in the discharge canal were all at or below 20 ug/L.

Zinc concentrations in river samples ranged from 120 ug/L at the downstream DAEC location (Station 3) on April 7 to <20 ug/L at Station 4 one half mile below the plant on the same date. Zinc values in the July river samples ranged from 20 to 50 ug/L. Manganese values in river samples were somewhat lower than those observed in 1993 ranging from 70 to 180 ug/L. Highest river manganese concentrations occurred in the July samples.

Reconcentration of solids in the blowdown discharge resulted in increased levels of chlorides, sulfates manganese and zinc in the discharge canal in both the April and July samples. The high sulfate levels in the discharge canal on both sampling dates, 690 and 920 mg/L were also the result of the addition of sulfuric acid for pH control in the cooling water. The results of the additional chemical determinations are given in Table 23.

Benthic Studies

Artificial substrate samples (Hester-Dendy) were placed at each of the four sampling locations upstream and downstream of the station and in the discharge canal on May 3 and August 16, 1994. These substrates were collected on June 9 and September 22, 1994 following a five week period to allow for the development of a benthic community.

As in previous years, the communities which developed on the substrates were far larger and more diverse than those which are normally found in the shifting sand and silt bottom characteristic of the Cedar River in the vicinity of the Duane Arnold Energy Center. A total of 34 taxa were identified during the two sampling periods, 32 in June and 23 in August. These included 27 species (7 orders) of insects , 1 specie of crustacean, 1 specie of snail, 3 species of annelids, 1 specie of nematode and 1 specie of flatworm. Blackfly (<u>Simulim</u>), midge (<u>Chironomid</u>) and various caddisfly (<u>Trichoptera</u>) larvae were the dominant organisms in the June and August river samples. With the exception of snails (<u>Physa</u>) which were common in June, the numbers of organisms in the discharge canal were far lower than at the river locations. Diversity was also far lower in the discharge canal, 13 species in June and only 7 species in August.

In general, there continued to be little difference in the overall composition of the benthic populations between upstream and downstream locations, although the number of organisms varied considerably.

The total numbers of organisms were substantially higher at the upstream DAEC location (Station 2) on the June substrate while on the August substrates somewhat higher numbers were present at the upstream (Lewis Access) station. Random differences in the number of organisms at the various locations has been observed during past studies and no consistent pattern has been apparent.

As in previous years, the artificial substrate studies indicate the Cedar River, both upstream and downstream of the Duane Arnold Energy Center, is capable of supporting a relatively diverse macroinvertebrate fauna in those limited areas where suitable bottom habitat is available. The results of the benthic studies are given in Table 24.

Asiatic Clam and Zebra Mussel Surveys

In past years a number of power generation facilities experienced problems with blockage of cooling water intake systems by large numbers of Asiatic clams (Corbicula sp.). Although this clam commonly occurs in portions of the Iowa reach of the Mississippi River, it is normally absent from areas with shifting sand/silt substrates such as occur in the Cedar River in the vicinity of the Duane Arnold Energy center. Corbicula has not been collected from the Cedar River in the vicinity of the DAEC during the routine monitoring program, which was implemented in April of 1971. A single Corbicula was, however, collected in January of 1979 in the vicinity of Lewis Access, upstream of DAEC, by Hazelton personnel. Because Corbicula has been reported on one occasion from the Cedar River and is commonly found in power plant intakes on the Mississippi River, studies were implemented at the Duane Arnold Energy Center in 1981 to determine if the organism was present in the vicinity of the station or had established itself within the system. No Corbicula were collected during the 1981 to 1993 investigations.

The zebra mussel (Dreissena polymorpha) is a European form which was first found in the United States in Lakes St. Clair and Erie in 1988. The zebra mussel has been a major problem in water intakes in Europe for many years and is now causing significant problems at many power plant intakes as well as a number of municipal water treatment plants in the United States. The organisms tend to grow in clumps attached to a solid substrate and can rapidly clog intake structures, screens, and pipes. It is difficult to control chemically and frequently must be removed mechanically. The mussel is adapted to both river and lake habitats and does especially well in enriched waters which support large plankton populations that it utilizes as food. Unlike the Asiatic clam (Corbicula), it is capable of living in cold waters and does not require a silty substrate.

Since its introduction into the United States the zebra mussel has rapidly expanded its range. It is now found in all of the Great Lakes and in 1991, just three years after they were first found in the U.S., they were collected in the Hudson, Illinois, Mississippi, Ohio, Susquehanna, Tennessee, and Cumberland Rivers.[25] The U.S. Army Corps of Engineers reports that zebra mussel populations have increased exponentially on lock and dam surfaces since their introduction into the Mississippi River in 1991[26] and it is now apparent that the organism also has established itself throughout the Iowa reach of the Mississippi River. Although it is impossible to make exact estimates, it is highly likely that the organism will continue to expand its range into the tributary streams of the Mississippi river within the nest few years. If it does colonize interior Iowa rivers, problems with intake structures at power plants in the area are likely to occur. As a result of these concerns, studies designed to detect the presence of the zebra mussel were first instituted in 1990. No zebra mussels were found during the 1990 to 1993 study.[20,21,22,23]

Studies to determine the presence of both the Asiatic clam and the zebra mussel were conducted on May 18 and September 21, 1994. Inspection were made in the Cedar River both upstream and downstream of the Duane Arnold Energy Center as well as between the bar racks and traveling screens, in the cooling towers and in the discharge canal. Substrates were placed near the discharge structure in the Pleasant Creek Reservoir during May 1994 and were examined during the September investigation to determine if colonization by zebra mussels had occurred. No Asiatic clams or zebra mussels were detected at any of the sites during either the May or September 1994 investigations.

Impingement Studies

The total number of fish impinged on the intake screens at the Duane Arnold Energy Center during 1994, as reported by Iowa Electric personnel, was higher than during 1993.[23] Daily counts indicated a total of 618 fish were impinged during 1994. Highest impingement rates continued to occur during the winter and early spring period. During the months of January to April and in December 580 fish, or approximately 94% of the yearly impingement total, were removed from the trash baskets. Lowest impingement rates occurred in September when only 2 fish were removed from the trash baskets. The month with the highest impingement rate was March, when 174 fish were collected in the trash baskets. The results of the daily trash basket counts are given in Table 25.

DISCUSSION AND CONCLUSIONS

In contrast to 1993 when the Cedar River experienced the highest flows present since the study was implemented in 1972, river flows during 1994 were near normal. The estimated mean flow of 4701 cfs was less than one third of that present in 1993 and slightly less than the average flow of 5312 cfs observed during the 23 years of the Cedar River water quality study. Although river flow and subsequent dilution of the cooling tower blowdown was far less than during the previous year, the impact of station operation on the water quality of the Cedar River was, as in previous years, minimal.

In 1994 the maximum ΔT value between ambient upstream temperatures (Station 2) and temperatures one half mile downstream of the plant (Station 4) was only 1.0°C (1.8°F) and average downstream temperatures were only 0.3°C (0.5°F) above ambient (Table 26). Obviously this increase is below the Iowa Water Quality standard of 3.0°C (5.4°F)[24] and would not adversely impact the biota or water quality of the river.

Other parameters at downstream locations also exhibited little or no effects from the discharge of the Duane Arnold Energy Center. Of all parameters which were routinely determined during the 1994 study only two, dissolved solids and iron, exhibited increased mean values at downstream locations. The greatest increases continued to be in dissolved solids with mean values of 289 and 305 mg/L respectively, an increase of only 6%. Mean downstream iron values were only 4% above upstream levels while hardness, phosphate and nitrate concentrations were similar or slightly lower at the downstream location (Table 26). Studies conducted in April and July indicated that heavy metal values at downstream locations were not consistently increased by station discharge, although wide variations in heavy metal values between river stations were observed. Only sulfates, which are added to the cooling towers in the form of sulfuric acid for pH control, exhibited increases at downstream locations during the April and July studies but again these increases were minimal (Table 23) and no violations of Iowa Water Quality standards[24] related to operation of the Duane Arnold Energy Center were observed during the 1994 studies.

The operation of the Duane Arnold Energy Center continued to have a minimal impact on the water quality of the Cedar River. However the effects of climatic and hydrological conditions are evident when 1993 and 1994 data are compared. Both average and maximum water temperatures were substantially higher in 1994 than in 1993. In 1994 the maximum ambient observed water temperature was 26.5°C (79.7°F) as compared to 22.5°C (72.5°F) in 1993. The 1994 water temperatures were generally similar to those of most past years. Other parameters were also affected by the lower flows and higher temperatures present in 1994. Turbidity and nitrate values were substantially lower than those observed in 1993. Mean nitrate values of 5.1 mg/L (as N) were present during the current year, the lowest observed since 1989 (Table 27). These low values may be in part related to the flushing of much of the nitrate from the basin during the high flows present in 1993. Relative loading values, obtained by multiplying average annual concentrations by cumulative runoff, are indications of the total volumes of substances carried by the river. Loading values for turbidity, phosphate and nitrate during 1994 were the lowest observed since 1990 (Table 28) and were also indicative of the flushing action of the heavy runoff present in 1993. Concentrations of several parameters were usually higher during the current year than in 1993. These included dissolved oxygen, pH and BOD. These higher levels appear to be due to increased algal photosynthesis resulting from lower river flows and turbidity and warmer waters.

During 1994 a total of 618 fish were impinged on the intake screens at the Duane Arnold Energy Center. While higher than those of the previous year the numbers still remain very low and impingement continues to have an insignificant impact on the river fishery.

Benthic populations which developed on artificial substrates placed in the river in 1994 were similar to those observed in past years and indicate that the Cedar River is capable of supporting a diverse benthic community when adequate substrate is available. Although the total number of organisms was higher at the upstream Lewis Access location (Station 1) than at other river locations, species diversity and composition was similar at all locations and it does not appear that station operation is adversely impacting the benthos of the river. In contrast to the river samples, diversity was substantially lower on the discharge canal substrates, and forms such as mayfly nymphs and caddisfly larvae was far less common.

Although no Asiatic clams or zebra mussels were detected during the current year study, the zebra mussel continues to expand its range and populations in the Mississippi River. Thus monitoring for this form should continue in order to institute appropriate control measures at the earliest sign of this organism in the vicinity of the Duane Arnold Energy Center.

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Table 1

Summary of Hydrological Conditions
Cedar River at Cedar Rapids*
1994

Date	Mean Monthly Discharge cfs	Percent of Median Discharge†
January	956	76
February	2207	130
March	7939	131
April	4377	65
May	4153	86
June	6039	111
July	7539	177**
August	5421	222**
September	4026	184**
October	5578	226**
November	4252	172**
December	3931	208**

*Data obtained from U.S. Geological Survey records
**In excess of the 75% quartile
†Based on 1961-1990 period.

Table 2

Temperature (°C) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	0.0	0.0	1.5	0.0	0.0
Jan-20	0.0	0.0	13.0	0.0	0.0
Feb-01	0.0	0.0	0.0	0.0	0.0
Feb-17	2.0	1.0	5.0	1.0	2.0
Mar-01	0.5	0.5	4.5	0.5	1.0
Mar-17	4.5	4.5	18.0	5.0	5.0
Apr-07	6.5	7.0	16.5	8.0	7.0
Apr-19	14.0	15.0	21.0	14.5	15.0
May-03	11.5	12.5	22.5	12.5	12.5
May-18	18.5	19.0	24.0	19.0	20.0
Jun-09	20.0	20.5	24.5	20.5	21.0
Jun-22	26.0	26.5	28.5	26.5	26.5
Jul-05	24.5	25.0	30.5	25.0	25.0
Jul-21	23.0	23.5	27.0	23.5	23.5
Aug-03	24.0	24.5	29.0	24.5	24.5
Aug-16	20.5	21.0	27.0	21.0	21.0
Sep-04	18.5	19.0	25.0	19.0	19.5
Sep-22	20.0	20.0	26.0	20.0	20.0
Oct-03	14.0	14.0	22.0	14.0	14.0
Oct-20	14.5	14.5	22.5	14.5	15.0
Nov-03	10.0	10.0	22.5	10.0	10.0
Nov-14	9.0	9.5	20.0	9.0	9.5
Dec-01	2.0	1.5	20.0	2.0	2.0
Dec-15	0.5	0.0	6.0	0.5	0.5

Table 3

Summary of Water Temperature Differentials
and Station Output During Periods of
Cedar River Sampling in 1994

Date	ΔT(°C) Upstream River (Sta. 2) vs. Discharge (Sta. 5)	ΔT(°C) Upstream River (Sta. 2) vs. Downstream River (Sta. 3)	ΔT(°C) Upstream River (Sta. 2) vs. Downstream River (Sta. 4)	Station Output (% Full Power)
Jan-06	1.5	0.0	0.0	99.8
Jan-20	13.0	0.0	0.0	99.8
Feb-01	0.0	0.0	0.0	99.8
Feb-17	4.0	0.0	1.0	99.9
Mar-01	4.0	0.0	0.5	99.8
Mar-17	13.5	0.5	0.5	99.8
Apr-07	9.5	1.0	0.0	99.9
Apr-19	6.0	-0.5	0.0	99.8
May-03	10.0	0.0	0.0	99.8
May-18	5.0	0.0	1.0	99.9
Jun-09	4.0	0.0	0.5	99.9
Jun-22	2.0	0.0	0.0	99.2
Jul-05	5.5	0.0	0.0	99.9
Jul-21	3.5	0.0	0.0	76.3
Aug-03	4.5	0.0	0.0	87.7
Aug-16	0.0	0.0	0.0	99.9
Sep-04	6.0	0.0	0.5	99.9
Sep-22	6.0	0.0	0.0	99.9
Oct-03	8.0	0.0	0.0	99.8
Oct-20	8.0	0.0	0.5	99.9
Nov-03	12.5	0.0	0.0	99.9
Nov-14	10.5	-0.5	0.0	99.9
Dec-01	18.5	0.5	0.5	38.4
Dec-15	6.0	0.5	0.5	99.6

Table 4

Turbidity (NTU) Values for the Cedar River
near the Duane Arnold Energy Center During 1994

	Sampling Locations				
Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	4	4	3	4	3
Jan-20	4	4	5	2	4
Feb-01	2	2	4	3	2
Feb-17	2	2	14	2	2
Mar-01	9	8	16	10	10
Mar-17	28	28	89	31	28
Apr-07	17	18	32	19	17
Apr-19	42	46	170	44	44
May-03	34	34	76	36	75
May-18	48	43	78	43	40
Jun-09	62	58	100	60	56
Jun-22	100	96	360	100	100
Jul-05	74	79	240	76	77
Jul-21	76	76	210	76	76
Aug-03	49	50	85	46	48
Aug-16	70	73	200	71	74
Sep-04	29	32	50	32	32
Sep-22	39	38	68	40	38
Oct-03	28	29	102	26	30
Oct-20	46	42	100	40	43
Nov-03	19	18	53	19	19
Nov-14	12	12	39	13	13
Dec-01	12	14	20	14	14
Dec-15	7	7	12	7	6

Table 5

Total Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	390	400	1400	400	400
Jan-20	400	410	1300	430	390
Feb-01	380	370	400	410	400
Feb-17	400	390	1500	430	410
Mar-01	310	290	1100	320	300
Mar-17	350	350	1700	420	350
Apr-07	330	330	1500	430	340
Apr-19	380	390	2000	380	370
May-03	360	360	1800	350	320
May-18	360	340	2600	340	360
Jun-09	390	360	1700	380	390
Jun-22	510	520	2500	520	530
Jul-05	470	460	2300	470	460
Jul-21	460	440	2200	440	450
Aug-03	430	410	1900	390	440
Aug-16	360	370	1900	360	360
Sep-04	340	330	1700	320	350
Sep-22	240	230	1400	230	260
Oct-03	440	480	2300	450	420
Oct-20	450	430	2300	440	440
Nov-03	370	360	2200	420	380
Nov-14	370	380	2000	390	390
Dec-01	370	360	440	370	380
Dec-15	400	410	1600	440	420

Table 6

Dissolved Solids (mg/L) Values for the Cedar River
near the Duane Arnold Energy Center During 1994

	Sampling Locations				
Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	340	340	1300	360	370
Jan-20	380	380	1100	370	380
Feb-01	360	360	360	390	360
Feb-17	380	370	1300	410	390
Mar-01	280	260	980	280	270
Mar-17	280	170	1400	330	280
Apr-07	170	260	1400	360	280
Apr-19	250	260	1600	260	270
May-03	240	240	1500	240	250
May-18	230	220	2300	220	240
Jun-09	200	210	1400	200	230
Jun-22	320	290	1900	330	310
Jul-05	280	280	1800	250	260
Jul-21	300	290	1700	260	290
Aug-03	290	270	1600	280	290
Aug-16	220	220	1400	220	320
Sep-04	260	250	1500	250	270
Sep-22	240	230	1400	230	260
Oct-03	340	340	1800	350	340
Oct-20	330	330	2000	340	320
Nov-03	360	310	1700	360	330
Nov-14	320	350	1800	340	330
Dec-01	300	330	390	330	320
Dec-15	370	370	1500	400	360

Table 7

Suspended Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-06	2	4	2	3	2
Jan-20	4	3	4	2	4
Feb-01	3	3	7	4	2
Feb-17	4	4	17	5	4
Mar-01	11	10	11	10	14
Mar-17	49	48	120	55	50
Apr-07	41	46	57	42	40
Apr-19	99	110	250	100	100
May-03	76	82	120	86	79
May-18	120	110	130	120	110
Jun-09	140	140	190	150	130
Jun-22	180	180	510	180	180
Jul-05	140	150	340	140	130
Jul-21	130	120	250	130	130
Aug-03	100	99	80	97	98
Aug-16	110	110	260	110	98
Sep-04	68	74	68	74	69
Sep-22	99	100	140	110	100
Oct-03	68	65	180	65	64
Oct-20	97	90	170	95	96
Nov-03	37	38	74	38	35
Nov-14	21	21	75	20	24
Dec-01	16	17	31	19	22
Dec-15	4	4	11	3	5

Table 8

Dissolved Oxygen (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1994

	Sampling Locations				
Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	14.1	13.0	11.1	13.0	12.9
Jan-20	12.8	11.4	9.9	11.4	12.0
Feb-01	12.5	11.5	13.0	11.4	12.6
Feb-17	12.8	11.6	9.2	11.6	12.1
Mar-01	13.3	11.5	11.4	11.6	12.2
Mar-17	12.0	12.4	9.2	12.0	12.1
Apr-07	13.3	14.8	10.2	14.0	15.0
Apr-19	12.6	12.8	8.3	12.5	12.9
May-03	14.1	14.6	6.9	14.9	15.3
May-18	12.5	12.8	7.2	12.6	14.0
Jun-09	12.5	14.5	6.7	14.3	15.0
Jun-22	7.4	7.0	6.6	7.4	7.5
Jul-05	8.5	8.2	5.4	8.0	7.9
Jul-21	7.7	7.8	6.6	8.0	8.0
Aug-03	10.1	10.6	4.1	10.2	10.8
Aug-16	8.8	8.9	6.6	9.0	8.9
Sep-04	12.0	12.8	8.0	13.0	13.7
Sep-22	9.8	9.8	7.0	10.0	10.1
Oct-03	11.0	10.5	8.3	10.6	10.6
Oct-20	9.4	9.1	7.1	8.9	9.4
Nov-03	11.3	11.3	6.5	11.2	11.4
Nov-14	12.0	11.9	8.1	11.8	11.7
Dec-01	13.5	13.6	9.0	13.3	13.2
Dec-15	14.0	13.8	9.0	13.8	13.8

Table 9

Carbon Dioxide (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	5	5	*	5	5
Jan-20	7	5	*	7	6
Feb-01	7	7	*	7	6
Feb-17	9	9	*	2	2
Mar-01	7	7	*	7	6
Mar-17	2	2	*	2	2
Apr-07	<1	<1	*	<1	<1
Apr-19	<1	<1	*	<1	<1
May-03	<1	<1	*	<1	<1
May-18	<1	<1	*	<1	<1
Jun-09	<1	<1	*	<1	<1
Jun-22	2	2	*	2	2
Jul-05	<1	<1	*	<1	<1
Jul-21	2	2	*	2	2
Aug-03	<1	<1	*	<1	<1
Aug-16	3	3	*	2	3
Sep-04	<1	<1	*	<1	<1
Sep-22	1	1	*	<1	<1
Oct-03	<1	<1	*	<1	<1
Oct-20	4	4	*	3	3
Nov-03	<1	<1	*	<1	<1
Nov-14	<1	<1	*	<1	<1
Dec-01	<1	<1	<1	<1	<1
Dec-15	<1	<1	*	<1	<1

*Unable to calculate

Table10

Total Alkalinity (mg/L-CaCO) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-06	252	246	162	246	258
Jan-20	264	252	116	244	260
Feb-01	236	240	230	258	246
Feb-17	232	224	130	222	229
Mar-01	176	176	196	178	176
Mar-17	192	190	84	188	190
Apr-07	172	172	74	164	160
Apr-19	170	164	80	166	162
May-03	168	166	80	168	170
May-18	138	136	100	140	138
Jun-09	140	140	86	140	142
Jun-22	200	200	198	*	202
Jul-05	208	206	120	206	200
Jul-21	206	208	100	204	204
Aug-03	200	200	110	198	200
Aug-16	138	138	100	144	134
Sep-04	168	164	118	162	160
Sep-22	142	140	112	140	134
Oct-03	238	238	164	236	240
Oct-20	240	240	108	242	238
Nov-03	258	254	116	242	252
Nov-14	252	236	112	244	238
Dec-01	236	232	278	236	232
Dec-15	262	256	160	254	256

*Laboratory Accident

Table11

Carbonate Alkalinity (mg/L-CaCO) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	<1	<1	<1	<1	<1
Jan-20	<1	<1	<1	<1	<1
Feb-01	<1	<1	<1	<1	<1
Feb-17	<1	<1	<1	<1	<1
Mar-01	<1	<1	<1	<1	<1
Mar-17	<1	<1	<1	<1	<1
Apr-07	8	8	<1	10	10
Apr-19	6	7	<1	6	8
May-03	10	10	<1	12	12
May-18	8	8	<1	10	8
Jun-09	12	12	<1	18	14
Jun-22	<1	<1	<1	<1	<1
Jul-05	2	2	<1	2	2
Jul-21	<1	<1	<1	<1	<1
Aug-03	2	4	<1	2	2
Aug-16	<1	<1	<1	<1	<1
Sep-04	6	6	<1	6	8
Sep-22	<1	<1	<1	2	2
Oct-03	8	6	<1	6	6
Oct-20	<1	<1	<1	<1	<1
Nov-03	8	6	<1	6	4
Nov-14	4	6	<1	6	4
Dec-01	6	8	20	8	8
Dec-15	6	4	<1	4	4

Table12

Units of pH Values for the Cedar River
near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	8.2	8.2	7.7	8.2	8.2
Jan-20	8.0	8.1	8.0	8.0	8.1
Feb-01	8.0	8.0	8.1	8.0	8.0
Feb-17	7.9	7.9	7.7	7.9	7.6
Mar-01	7.9	7.9	7.7	7.9	7.9
Mar-17	8.3	8.3	7.8	8.3	8.3
Apr-07	8.7	8.7	8.1	8.6	8.7
Apr-19	8.6	8.7	7.7	8.6	8.8
May-03	8.7	8.8	7.7	8.8	8.9
May-18	8.8	8.8	7.9	8.8	8.8
Jun-09	8.8	9.0	7.6	9.0	9.1
Jun-22	8.3	8.3	7.7	8.3	8.3
Jul-05	8.4	8.4	7.7	8.4	8.4
Jul-21	8.2	8.2	7.8	8.2	8.2
Aug-03	8.4	8.5	7.6	8.5	8.5
Aug-16	8.0	8.0	7.7	8.1	8.1
Sep-04	8.5	8.5	7.8	8.6	8.7
Sep-22	8.3	8.3	7.6	8.4	8.4
Oct-03	8.4	8.4	7.9	8.4	8.4
Oct-20	8.2	8.2	7.7	8.3	8.3
Nov-03	8.5	8.5	7.7	8.6	8.6
Nov-14	8.6	8.5	8.0	8.6	8.5
Dec-01	8.6	8.6	8.9	8.6	8.6
Dec-15	8.4	8.4	8.1	8.4	8.4

Table13

Total Hardness (mg/L-CaCO) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	315	320	870	320	315
Jan-20	355	350	785	355	355
Feb-01	295	330	545	340	310
Feb-17	300	395	865	310	305
Mar-01	205	245	680	235	220
Mar-17	265	260	970	290	245
Apr-07	228	233	883	278	238
Apr-19	235	225	1000	240	230
May-03	224	214	944	214	216
May-18	194	198	1500	200	206
Jun-09	200	200	865	190	200
Jun-22	275	275	1240	285	285
Jul-05	260	280	1230	255	280
Jul-21	265	280	1220	260	250
Aug-03	250	230	1070	245	245
Aug-16	210	205	935	210	200
Sep-04	215	225	985	210	220
Sep-22	205	205	950	205	205
Oct-03	290	300	1320	285	305
Oct-20	280	290	1280	290	295
Nov-03	340	325	1360	360	330
Nov-14	325	305	1220	305	315
Dec-01	280	280	340	290	280
Dec-15	375	320	1050	340	330

Table14

Calcium Hardness (mg/L-CaCO) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	235	200	665	230	210
Jan-20	230	250	575	245	235
Feb-01	200	200	230	210	210
Feb-17	205	210	596	200	205
Mar-01	140	130	461	140	145
Mar-17	165	160	660	185	175
Apr-07	120	150	565	170	135
Apr-19	130	150	650	130	120
May-03	122	115	555	115	122
May-18	100	95	847	90	95
Jun-09	90	90	460	85	95
Jun-22	190	180	818	180	180
Jul-05	170	170	810	170	180
Jul-21	180	185	808	195	185
Aug-03	170	155	675	150	150
Aug-16	130	135	620	125	125
Sep-04	110	110	590	120	125
Sep-22	95	85	520	110	100
Oct-03	215	210	905	200	200
Oct-20	200	200	875	200	205
Nov-03	225	220	895	215	215
Nov-14	265	200	795	215	215
Dec-01	200	190	230	200	190
Dec-15	220	210	690	230	225

Table 15

Total Phosphorus (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	0.4	0.4	0.6	0.3	0.1
Jan-20	0.5	0.5	0.6	0.6	0.6
Feb-01	0.2	0.2	0.2	0.2	0.2
Feb-17	<0.1	<0.1	1.1	<0.1	<0.1
Mar-01	0.3	0.3	1.2	0.3	0.3
Mar-17	0.9	0.9	1.6	0.9	0.8
Apr-07	0.2	0.2	1.8	0.3	0.2
Apr-19	0.3	0.2	2.2	0.2	0.3
May-03	0.2	0.2	2.1	0.2	0.2
May-18	0.1	0.1	2.0	0.1	0.1
Jun-09	0.5	0.5	2.1	0.5	0.5
Jun-22	0.5	0.4	3.0	0.4	0.4
Jul-05	0.3	0.3	2.2	0.3	0.3
Jul-21	0.3	0.4	2.2	0.4	0.3
Aug-03	0.2	0.2	1.7	0.2	0.2
Aug-16	0.4	0.3	2.4	0.3	0.4
Sep-04	0.2	0.1	2.0	0.1	0.2
Sep-22	0.2	0.2	2.4	0.2	0.2
Oct-03	0.2	0.2	2.6	0.2	0.3
Oct-20	0.2	0.2	2.1	0.2	0.2
Nov-03	0.2	0.2	2.1	0.2	0.2
Nov-14	0.1	0.2	1.2	0.1	0.2
Dec-01	0.1	<0.1	0.1	0.1	0.2
Dec-15	0.1	0.1	0.1	0.1	0.8

Table 16

Soluble Orthophosphate (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	0.2	0.2	0.2	0.1	0.1
Jan-20	0.1	0.1	0.5	0.2	0.2
Feb-01	0.2	0.2	0.2	0.2	0.2
Feb-17	<0.1	<0.1	0.6	<0.1	<0.1
Mar-01	0.2	0.3	0.8	0.3	0.3
Mar-17	0.4	0.3	1.6	0.4	0.3
Apr-07	<0.1	<0.1	0.3	<0.1	<0.1
Apr-19	<0.1	<0.1	0.7	<0.1	<0.1
May-03	<0.1	<0.1	0.6	<0.1	<0.1
May-18	<0.1	<0.1	0.9	<0.1	<0.1
Jun-09	0.1	<0.1	0.6	<0.1	<0.1
Jun-22	0.1	0.1	1.1	0.1	0.1
Jul-05	0.1	0.1	0.9	0.1	0.1
Jul-21	0.2	0.2	1.0	0.2	0.1
Aug-03	<0.1	<0.1	0.8	<0.1	<0.1
Aug-16	0.1	0.2	1.0	0.2	0.2
Sep-04	<0.1	<0.1	0.7	<0.1	<0.1
Sep-22	<0.1	<0.1	0.8	<0.1	<0.1
Oct-03	<0.1	<0.1	0.9	<0.1	0.1
Oct-20	0.1	0.1	0.1	0.1	0.1
Nov-03	<0.1	<0.1	0.7	0.1	0.1
Nov-14	<0.1	<0.1	0.5	<0.1	<0.1
Dec-01	<0.1	<0.1	0.1	<0.1	<0.1
Dec-15	0.1	0.1	0.5	0.1	0.1

Table 17

Ammonia (mg/L-N) Values for the Cedar River
near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	0.2	0.2	0.2	0.3	0.2
Jan-20	0.5	0.4	<0.1	0.4	0.4
Feb-01	0.5	0.6	0.6	0.6	0.6
Feb-17	0.6	0.6	0.2	0.6	0.6
Mar-01	0.6	0.7	<0.1	0.7	0.6
Mar-17	0.9	0.9	0.7	0.9	0.9
Apr-07	0.1	0.1	0.1	<0.1	<0.1
Apr-19	<0.1	<0.1	0.1	<0.1	<0.1
May-03	<0.1	<0.1	0.2	<0.1	<0.1
May-18	<0.1	<0.1	0.1	<0.1	<0.1
Jun-09	<0.1	<0.1	0.2	<0.1	<0.1
Jun-22	<0.1	<0.1	0.2	<0.1	<0.1
Jul-05	<0.1	<0.1	0.2	<0.1	<0.1
Jul-21	<0.1	<0.1	<0.1	<0.1	<0.1
Aug-03	<0.1	<0.1	0.2	<0.1	<0.1
Aug-16	<0.1	<0.1	0.1	<0.1	<0.1
Sep-04	<0.1	<0.1	0.2	<0.1	<0.1
Sep-22	<0.1	<0.1	0.3	<0.1	<0.1
Oct-03	<0.1	<0.1	0.3	<0.1	<0.1
Oct-20	<0.1	<0.1	0.1	<0.1	<0.1
Nov-03	<0.1	<0.1	0.2	<0.1	<0.1
Nov-14	<0.1	<0.1	0.2	<0.1	<0.1
Dec-01	<0.1	<0.1	0.2	<0.1	<0.1
Dec-15	0.2	0.3	0.7	0.3	0.3

Table 18

Nitrate (mg/L-N) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	6.4	6.6	13	6.5	6.5
Jan-20	6.1	6.2	12	6.4	6.4
Feb-01	5.8	5.9	6.0	6.0	6.1
Feb-17	5.3	5.3	13	5.6	5.5
Mar-01	5.1	5.1	9.8	5.2	4.9
Mar-17	4.3	4.4	16	5.0	4.4
Apr-07	3.6	3.5	12	4.2	3.6
Apr-19	4.0	4.0	17	4.1	4.1
May-03	3.7	3.6	3.8	3.6	3.6
May-18	3.3	3.2	21	3.3	3.3
Jun-09	2.7	2.6	9.4	2.6	2.7
Jun-22	6.6	6.7	28	6.7	6.9
Jul-05	6.6	6.6	26	6.6	6.0
Jul-21	7.0	7.5	25	7.0	7.0
Aug-03	4.6	4.5	15	4.7	4.0
Aug-16	4.2	4.1	13	4.1	4.1
Sep-04	2.9	2.8	11	2.8	1.8
Sep-22	1.6	1.5	6.9	1.6	1.6
Oct-03	6.4	6.5	21	6.5	6.7
Oct-20	6.4	6.6	21	6.6	6.6
Nov-03	6.0	6.0	21	6.1	6.1
Nov-14	5.4	5.4	20	5.5	5.6
Dec-01	6.2	6.2	6.5	6.2	6.3
Dec-15	7.2	7.4	14	7.6	7.5

Table 19

Total Iron (mg/L) Values for the Cedar River
near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	0.08	0.08	0.24	0.08	0.07
Jan-20	0.10	0.09	0.09	0.10	0.27
Feb-01	0.09	0.10	0.14	0.11	0.10
Feb-17	0.09	0.08	0.46	0.09	0.09
Mar-01	0.32	0.29	0.62	0.30	0.30
Mar-17	0.52	0.55	1.7	0.59	0.52
Apr-07	0.48	0.41	1.1	0.46	0.37
Apr-19	0.42	0.42	1.8	0.42	0.41
May-03	0.20	0.24	1.0	0.22	0.23
May-18	0.45	0.43	1.4	0.41	0.44
Jun-09	0.59	0.57	1.5	0.55	0.53
Jun-22	1.5	1.4	4.6	1.4	1.4
Jul-05	0.78	0.76	2.8	0.85	0.78
Jul-21	4.7	4.2	10	4.2	4.3
Aug-03	0.33	0.29	0.68	0.30	0.35
Aug-16	1.1	1.1	3.5	1.0	1.1
Sep-04	0.86	0.95	2.0	0.92	1.0
Sep-22	0.97	1.0	2.6	1.0	1.1
Oct-03	1.6	1.7	5.3	1.6	1.6
Oct-20	2.9	2.4	5.9	2.4	2.6
Nov-03	0.99	0.99	3.1	1.0	1.0
Nov-14	0.60	0.64	2.4	0.65	0.68
Dec-01	0.68	0.72	1.0	0.70	0.79
Dec-15	0.19	0.14	0.68	0.19	0.19

Table 20

Biochemical Oxygen Demand (5-day in mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1994

	Sampling Locations				
Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	3	3	2	2	2
Jan-20	<1	<1	1	1	<1
Feb-01	1	2	1	<1	2
Feb-17	<1	<1	1	1	<1
Mar-01	2	2	2	3	2
Mar-17	3	3	5	3	3
Apr-07	6	8	13	8	7
Apr-19	9	9	18	10	10
May-03	11	12	22	12	12
May-18	13	13	20	13	14
Jun-09	18	19	25	19	14
Jun-22	6	6	6	4	4
Jul-05	3	3	12	3	4
Jul-21	2	3	5	2	2
Aug-03	6	7	7	6	6
Aug-16	2	2	6	2	2
Sep-04	13	13	16	13	13
Sep-22	14	14	23	14	14
Oct-03	2	2	10	2	2
Oct-20	2	3	9	2	3
Nov-03	4	4	12	10	10
Nov-14	2	2	8	3	2
Dec-01	2	2	2	2	2
Dec-15	<1	<1	2	<1	2

Table 21

Coliform Bacteria (Fecal Organisms/100 ml) Values for the Cedar River near the Duane Arnold Energy Center During 1994

	Sampling Locations				
Date 1994	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	90	80	60	210	240
Jan-20	1500	1500	90	1100	960
Feb-01	640	860	410	580	510
Feb-17	790	690	170	530	300
Mar-01	220	140	180	120	160
Mar-17	610	390	580	360	420
Apr-07	20	20	40	30	<10
Apr-19	170	60	20	100	60
May-03	120	60	20	110	100
May-18	50	50	400	54	30
Jun-09	73	82	60	130	91
Jun-22	770	780	>4200	730	710
Jul-05	8500	7400	340	9500	9200
Jul-21	4000	2100	2800	3200	2600
Aug-03	120	82	700	55	82
Aug-16	930	870	440	940	00,830
Sep-04	110	110	1400	100	80
Sep-22	90	110	600	60	50
Oct-03	480	330	130	280	450
Oct-20	1110	830	280	930	890
Nov-03	370	320	110	310	270
Nov-14	300	140	140	240	200
Dec-01	500	450	270	440	440
Dec-15	64	280	820	240	150

Table 22

Coliform Bacteria (E. coli/100 ml) Values for the Cedar River near the Duane Arnold Energy Center During 1994

Date 1994	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 Feet Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan-06	10	30	<10	10	40
Jan-20	480	180	20	550	150
Feb-01	250	340	50	270	40
Feb-17	130	100	60	80	20
Mar-01	40	50	10	10	<10
Mar-17	330	180	310	160	140
Apr-07	<10	<10	<10	<10	<10
Apr-19	160	70	10	80	70
May-03	20	50	<10	<10	<10
May-18	10	10	290	30	27
Jun-09	100	82	40	110	90
Jun-22	810	700	4100	670	620
Jul-05	6000	4700	300	6700	5000
Jul-21	1900	1800	2400	1800	2100
Aug-03	120	36	73	90	82
Aug-16	740	600	370	710	730
Sep-04	80	100	700	110	90
Sep-22	70	80	100	40	27
Oct-03	34	370	91	260	300
Oct-20	1110	830	180	950	700
Nov-03	300	200	160	270	270
Nov-14	120	200	110	150	80
Dec-01	210	310	150	230	260
Dec-15	10	180	750	170	130

Table 23

Additional Chemical Analysis-1994

Station	Cl^- (mg/L)	SO_4^{-2} (mg/L)	Metals (ug/L) Cr	Cu	Pb	Mn	Hg	Zn
			Apr-07					
1. Lewis Access	22	35	<20	<10	<10	70	<1	40
2. Upstream DAEC	22	36	<20	<10	<10	70	<1	90
3. Downstream DAEC	26	98	<20	<10	26	80	<1	120
4. One-half mile below plant	22	45	<20	<10	<10	70	<1	<20
5. Discharge Canal	72	690	<20	<10	<10	170	<1	360
			Jul-21					
1. Lewis Access	15	23	<20	60	10	180	<1	50
2. Upstream DAEC	16	23	<20	10	<10	170	<1	20
3. Downstream DAEC	15	22	<20	<10	<10	170	<1	40
4. One-half mile below plant	16	26	<20	20	<10	170	<1	50
5. Discharge Canal	71	920	<20	10	<10	390	<1	340

Table 24

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from the Cedar River and the discharge canal in the vicinity of the Duane Arnold Energy Center, 5/3/94-6/9/94.

Taxon	Collection Site				
	Lewis Access	U/S DAEC	D/S DAEC	½ mi below plant	Disc. Canal
Platyhelminthes					
Turbellaria					
Tricladida					
Planariidae					
Dugesia tigrina	1				155
Nematoda		2			
Mollusca					
Gastropoda					
Limnophila					
Physidae					
Physa spp.					1127
Annelida					
Hirudinea					
Erpobdellidae					3
Oligochaeta					
Lumbriculidae					1
Tubificidae	1	58			3
Arthropoda					
Crustacea					
Amphipoda					
Talitridae					
Hyallela azteca					1
Insecta					
Coleoptera (Beetles)					
Elmidae					
Optioservus spp.		2		1	
Stenelmis spp.	1			1	
Diptera					
Chironomidae	22	189	39	21	8
Simuliidae					
Simulium spp.	39	1272	297	8	20
Empididae					
Hemerodromia spp.		3			
Ephemeroptera (Mayflies)					
Baetidae					
Baetis spp.	23	20	3	3	
Caenidae					
Caenis spp.		2	2	2	
Heptageniidae					
Heptagenia diabasia	39				
Heptagenia spp.	32	75	22	27	2
Stenonema pulchellum	8				
Stenonema spp.		4	1	2	1
Oligoneuriidae					
Isonychia spp.	109	125	73	18	1
Tricorythidae					
Tricorythodes spp.	2	32		11	
Hemiptera					
Hebridae					
Hebrus sp.		1			

Table 24 (con't)

Taxon	Lewis Access	U/S DAEC	Collection Site D/S DAEC	1/2 mi below plant	Disc. Canal
Plecoptera (Stoneflies)					
Perlidae					
Perlesta spp.	44	24	25	4	
Pteronarcidae					
Pteronarcys spp.			1		
Trichoptera (Caddisflies)					1
Hydropsychidae (larvae)	69				
Hydropsychidae (pupae)	141	51	33	15	
Hydropsychidae (adult)	2	1			
Ceratopsyche bronta			1		
Ceratopsyche morosa (bifida form)	3	4			
Cheumatopsyche spp.	336	218	243	76	
Hydrcpsyche bidens	92	126	94	54	
Hydropsyche orris	5	26	9		
Hydropsyche simulans	14	29	21	12	
Hydropsyche spp.		66	8	11	
Potamyia spp.			1	2	
Leptoceridae					
Ceraclea sp.					1
Triaenodes sp.	1				
Total Organisms	**984**	**2330**	**873**	**268**	**1324**
No. Organisms/m^2	**9840**	**23,330**	**873**	**2680**	**13,240**

Samples were collected using Hester-Dendy artifical substrate samplers. Samplers were composed of five plates measuring approximately 0.01 m^2 per side per plate.

Table 24 (con't)

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from the Cedar River and the discharge canal in the vicinity of the Duane Arnold Energy Center, 8/16/94-9/22/94.

Taxon	Collection Site					
	Lewis Access	U/S DAEC	D/S	DAEC	½ mi below plant	Disc. Canal
Platyhelminthes						
Turbellaria						
Tricladida						
Planariidae						24
Annelida						
Oligochaeta						
Lumbriculidae						
Tubificidae	5	4	12	84	28	11
"Megadrile"						1
Arthropoda						
Insecta						
Coleoptera (Beetles)						
Elmidae						
Stenelmis spp.			4			
Diptera						
Chironomidae	927	696	660	1064	432	26
Simuliidae						
Simulium spp.	112	13		4	12	
Empididae						
Hemerodromia spp.	3	8	8	13	11	
Ephemeroptera (Mayflies)						
Baetidae						
Baetis spp.	4	16	3	8	6	
Caenidae						
Caenis spp.			1			
Heptageniidae						
Heptagenia spp.	13	29	49	24	40	
Stenonema spp.	10	32	98	38	45	
Oligoneuriidae						
Isonychia spp.		4	15	6	10	
Tricorythidae						
Tricorythodes spp.			9	2	9	
Odonata						
Coenagrionidae						
Anomalagrion/Ischnura sp.						1
Plecoptera (Stoneflies)						
Perlidae						
Acroneuria spp.		2				
Perlesta spp.			1			
Trichoptera (Caddisflies)						
Hydropsychidae (pupae)			1			
Ceratopsyche morosa (bifida form)				1		
Cheumatopsyche spp.	2	1	2	7	8	
Hydropsyce betteni	1					
Hydropsyche bidens	589	224	116	125	145	
Hydropsyche orris	79	13	14	17	13	
Hydropsyche simulans	303	104	120	150	160	1
Hydropsyche spp.	24	20	2	3	4	
Potamyia spp.	68	7	18	25	5	1
Total Organisms	**2140**	**1173**	**1133**	**1571**	**928**	**65**
No. Organisms/m^2	**21,400**	**11,730**	**11,330**	**15,710**	**9,280**	**650**

***Duplicate sample**

Samples were collected using Hester-Dendy artifical substrate samplers. Samplers were composed of five plates measuring approximately 0.01 m^2 per side per plate.

Table 25

Daily Numbers of Fish Impinged at the Duane Arnold Energy Center
January-December 1994

Day of the Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	6	4	1	2	0	0	0	0	0	0	0	1
2	5	0	1	0	0	0	0	0	1	0	1	0
3	2	4	16	2	0	0	0	0	0	0	2	3
4	7	1	6	15	0	0	0	0	0	0	0	0
5	12	0	4	14	0	0	0	0	0	0	0	0
6	5	0	8	20	0	0	1	0	0	0	0	0
7	4	1	10	5	0	0	0	0	0	0	0	0
8	1	0	4	4	0	1	0	0	0	0	0	0
9	5	0	5	2	0	0	0	0	0	0	0	0
10	1	0	5	0	0	0	0	0	0	0	1	0
11	12	0	3	0	1	1	0	0	0	0	0	2
12	5	0	8	1	0	0	0	0	0	0	3	0
13	9	0	11	0	0	0	0	0	0	0	0	2
14	14	0	4	0	1	0	0	0	0	0	1	0
15	5	0	10	2	0	0	0	0	0	0	0	0
16	4	40	2	7	0	1	0	0	0	0	0	0
17	1	29	1	5	0	0	0	0	0	0	0	0
18	4	8	8	3	0	0	0	2	0	0	0	0
19	1	6	4	1	0	0	0	0	0	0	0	0
20	2	7	6	7	0	0	0	0	0	0	0	0
21	0	8	3	0	2	0	0	0	0	1	0	0
22	5	5	2	0	0	0	0	0	0	1	0	3
23	4	5	1	0	0	0	0	0	0	0	1	1
24	0	3	1	0	0	0	0	*	0	0	2	1
25	4	3	17	3	0	0	1	0	0	0	2	2
26	1	1	2	1	0	0	0	0	0	0	2	0
27	0	1	16	1	0	0	1	0	0	0	0	10
28	0	4	6	0	0	0	0	0	0	0	0	22
29	0	-	2	0	0	0	0	0	0	1	1	7
30	0	-	8	0	0	0	0	0	1	0	3	3
31	0	-	0	-	0	-	0	2	-	0	0	5
Total	119	130	174	95	4	3	3	4	2	3	19	62
Annual Total	618											

*No Data

Table 26

Comparison of Average Values for Several Parameters at Upstream, Downstream, and Discharge Canal Locations at the Duane Arnold Energy Center During Periods Of Station Operation-1994

Parameters	Upstream (Sta. 2)	Discharge Canal (Sta. 5)	Downstream (Sta.4)
Temperature (°C)	12	18.1	12.3 (103%)*
Dissolved Solids (mg/L)	289	1464	305 (106%)
Total Hardness (mg/L)	270	1004	268 (99%)
Total Phosphate (mg/L)	0.27	1.7	0.27 (100%)
Nitrate (mg/L as N)	5.1	15.1	5.1 (100%)
Iron (mg/L)	0.81	2.28	0.84 (104%)

*Percent of upstream level ()

Table 27

Comparison of Average Yearly Values for Several Parameters in the Cedar River Upstream of the Duane Energy Center*
1972-1994

Year	Mean flow** (cfs)	Turbidity (NTU)	Total PO_4 (mg/L)	Ammonia (mg/L-N)	Nitrate (mg/L-N)	BOD (mg/L)	Total Hardness (mg/L)
1972	4,418	22	1.10	0.56	0.23	5.7	253
1973	7,900	28	0.84	0.36	1.5	4.0	250
1974	5,580	29	2.10	0.17	4.2	4.7	266
1975	4,206	58	1.08	0.33	2.8	6.5	251
1976	2,082	41	0.25	0.25	2.8	7.3	233
1977	1,393	15	0.33	0.52	2.9	6.5	243
1978	3,709	23	0.26	0.22	4.4	3.3	261
1979	7,041	26	0.29	0.12	6.6	2.5	272
1980	4,523	40	0.34	0.19	5.4	4.3	238
1981	3,610	33	0.77	0.24	6.0	6.5	279
1982	7,252	43	0.56	0.23	8.0	5.1	274
1983	8,912	22	0.25	0.10	8.6	3.3	259
1984	7,325	40	0.32	0.10	5.9	3.9	264
1985	3,250	30	0.31	0.11	4.8	6.7	245
1986	6,375	33	0.26	0.10	6.8	3.7	285
1987	2,625	32	0.24	0.06	5.6	5.8	269
1988	1,546	28	0.30	<0.16	2.8	9.6	246
1989	947	24	0.37	0.30	1.5	10.3	224
1990	5,061	33	0.29	0.20	7.3	4.8	283
1991	8,085	65	0.38	0.20	7.9	4.3	268
1992	5,717	49	0.31	0.16	6.4	5.5	261
1993	15,900	44	0.27	0.16	6.2	2.3	276
1994	4,701	34	0.28	0.22	5.1	5.3	269

*Data from Lewis Access location (Station 1)
**Data from U.S. Geological Survey Cedar Rapids gauging station

Table 28

Summary of Relative Loading Values (Average Annual Concentration x Cumulative Runoff) for Several Parameters in the Cedar River Upstream of the Duane Energy Center*
1972-1994

Year	Mean Flow (cfs)	Cumulative** Runoff (in)	Turbidity	Relative Loading Values Total PO_4	Ammonia	Nitrate	BOD
1972	4,418	9.24	203	10.2	5.2	2	53
1973	7,900	16.48	461	13.8	5.9	25	66
1974	5,580	11.64	338	24.4	2.0	49	55
1975	4,206	8.77	509	9.5	2.9	25	57
1976	2,082	4.35	178	1.1	1.1	12	32
1977	1,393	2.91	44	1.0	1.5	8	19
1978	3,709	7.74	178	2.0	1.7	34	26
1979	7,041	14.79	385	4.3	1.8	98	37
1980	4,523	9.45	378	3.2	1.8	51	41
1981	3,610	7.53	248	5.8	1.8	45	49
1982	7,252	15.13	651	8.5	3.5	121	77
1983	8,912	18.00	396	4.5	1.8	155	59
1984	7,325	15.22	609	4.9	1.5	90	59
1985	3,250	6.80	204	2.1	0.8	33	46
1986	6,475	13.11	433	3.4	1.3	89	49
1987	2,625	4.85	155	1.2	0.3	27	28
1988	1,546	2.85	80	0.9	<0.4	8	27
1989	947	1.84	44	0.7	0.6	3	19
1990	5,061	9.34	308	2.7	1.9	68	45
1991	8,085	17.15	1115	6.5	3.4	135	74
1992	5,717	10.92	535	3.4	1.7	70	61
1993	15,900	32.39	1425	8.8	5.2	201	74
1994	4,701	10.45	355	2.9	2.3	53	55

*Data from Lewis Access location (Station 1)
**Data from U.S. Geological Survey Cedar Rapids gauging station